NASA Earth Science Missions

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NASA Earth Science Missions

NASA's Vision:

To improve life here,

To extend life to there,

To find life beyond

NASA Earth Science Missions

NASA's Mission:

To understand and protect our home planet,

to explore the universe and search for life,

to inspire the next generation of explorers,

… as only NASA can.

NASA Earth Science Missions

The Earth Science Enterprise is one of NASA's 4 enterprises:

- Earth Science Enterprise
- Space Science Enterprise
- Aeronautics
- Human Exploration and Development of Space

NASA Earth Science Missions

The Earth Science Enterprise answers several of NASA's goals:

Goal 1: Understand Earth's system and apply Earth-system science to improve the prediction of climate, weather, and natural hazards.

Goal 3: Create a more secure world and improve the quality of life by investing in technologies and collaborating with other agencies, industry, and academia.

NASA Earth Science Missions

The Earth Science Enterprise includes:

- Exploratory Missions to make new or one-time observations,
- Systematic Measurement Missions to produce long-term data sets,
- Technology Demonstration/Operational Precursor Missions, which prove out new technologies before they can be used at reasonable risk on other missions, and
- Missions constructed for other agencies, e.g., NOAA.

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Once upon a time, there was a ~~15~~ 18 year plan (circa 1992):

EOS-A ➔ EOS AM-1' ➔ EOS AM-2' ➔ EOS AM-3'

➔ EOS PM-1' ➔EOS PM-2' ➔ EOS PM-3'

EOS-B

➔ EOS CHEM-1 ➔ EOS CHEM-2 ➔ EOS CHEM-3

The "big 2" to "big 3", plus some much smaller missions.

NOTE: * indicates X-band usage; ' indicates direct broadcast only.

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Then there was a paradigm shift (faster, better, cheaper!):

EOS AM-1'	→TERRA'	→	A fleet of smaller 1- or 2-
EOS PM-1*'	→AQUA*'	→	instrument spacecraft
EOS CHEM-1*	→AURA*	→	(and at less risk)
Alt	→ICESAT*	→	

Until 1996, larger spacecraft communications were:

- Mostly via the NASA Tracking and Data Relay Satellite System,
- A backup science data link via direct-to-ground X-Band, and
- A direct broadcast service via direct-to-ground X-Band.

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The pressure for smaller, faster, and cheaper spacecraft drove the use of direct-to-ground communications using X-Band (and, we anticipate, Ka-Band).

Two ground stations were constructed to support this policy:

- in Poker Flat, Alaska (NE of Fairbanks, 65N), and the other
- on a plateau above Longyearbyen, Svalbard (Spitzbergen, 79N).

NASA also left the ground station business; the management of these stations will be discussed in later papers.

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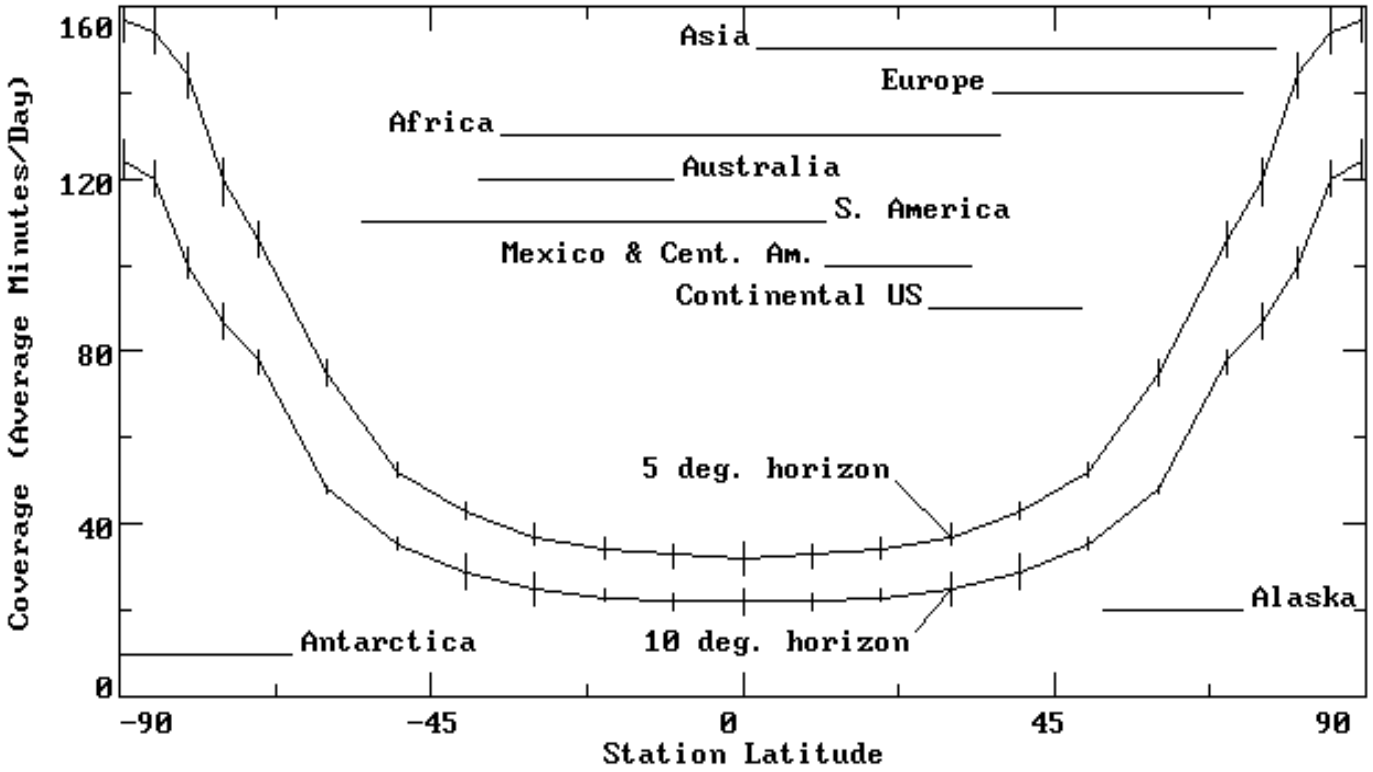
The two high latitude stations guaranteed at least one contact per orbit and adequate contact time per day.



Station Coverage versus Latitude for EOS AM, PM, and CHEM Flights

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The X-band ground stations primarily used by NASA include:

Poker Flat, AK (Fairbanks area)

Svalbard, Norway

Wallops Island, VA

McMurdo, Antarctica (primarily RADARSAT)

Alaska SAR Facility, Fairbanks, AK
(International S/C, receive only)

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But what about same place, same time imaging?

(This capability was lost when instruments were spread over many satellites.)

Answer – Coordinated observations made by a set of satellites flying in "trains" over the same ground swath . This strategy is sometimes called formation flying, constellations of spacecraft. This strategy results in same place, almost same time imaging.

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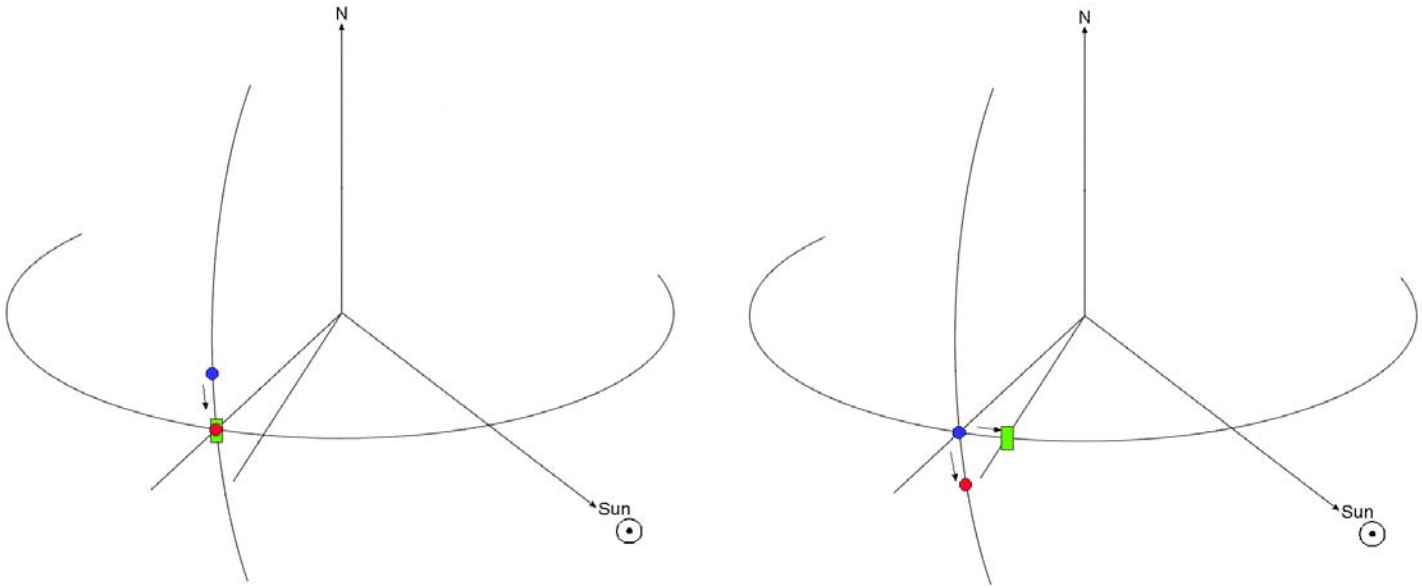
Two Spacecraft, Same Orbit Trajectory



These spacecraft view different scenes on the surface of the earth due to the Earth's rotation under their orbit plane.

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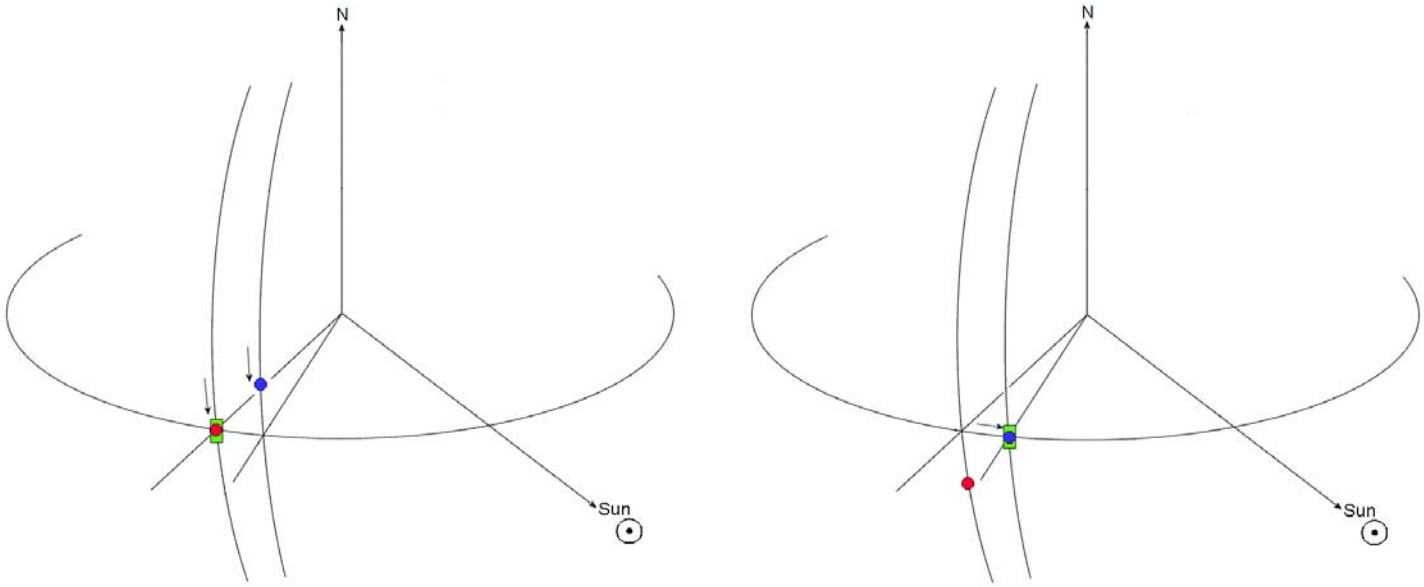
Two Spacecraft, Same Ground Trajectory



The orbit planes are offset so that each spacecraft passes over the same point on the ground at slightly different times.

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NASA is planning 2 such trains:

- **A morning train led by Landsat 7* with TERRA' bringing up the rear, and**
- **An afternoon train led by AQUA* with AURA* bringing up the rear.**

The trains will be coordinated to avoid overloading the ground stations:

- **The "caboose" of the morning train leads the "engine" of the afternoon train by 20 minutes, and**
- **The "caboose of the afternoon train leads the "engine" of the morning train by 40 minutes.**

These trains will be described later in the paper on constellations.

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Because NASA is primarily an R&D agency, a further thrust was added to hand off operational missions to operational agencies or to the commercial sector:

AQUA*'	**➔ NPP*'**	**➔ NPOESS'**
		(NOAA, DoD, NASA)
Landsat 7*	**➔ Landsat* (USGS)**	**➔ LDCM*(?) (data buy)**
		(Commercial vendor)

Currently Landsat 7 and Landsat 5 are operated by the United States Geological Survey. Their operation and the international cooperators they also serve will be discussed in a later paper.

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International collaborative missions still continue:

ADEOS-2* (MIDORI, multipurpose), with Japan

CALIPSO (aerosols and clouds), with France

ERS-2*(multipurpose, incl. SAR), receive data from ESA

GRACE (x2, gravity measurement), with Germany

JASON-1(oceanography), with France

SAC-C*(multispectral imager), launched for Argentina

PARASOL (polarimeter), French mission in afternoon train

RADARSAT-1*(SAR), launched for Canada

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The New Millennium Program (NMP) demonstrates new technology:

EO-1* Advanced Land Imager, Hyperspectral Imager, etc.

EO-3 Geosynchronous Imaging Fourier Transform Spectrometer

Demonstration of coordinated observations:

Using MODIS on TERRA to “steer” Hyperion on EO-1.

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Relatively inexpensive science missions such as in the Earth System Science Pathfinder (ESSP) program include:

ACRIMSAT (solar irradiance)

AQUARIUS (ocean salinity)

CLOUDSAT (cloud radar, with DoD)

GRACE (gravity, with the Germans)

HYDROS* (soil moisture)

Orbiting Carbon Observatory* (OCO)

QuikSCAT (replaced seawinds on ADEOS-1)

SORCE* (solar irradiance)

NASA Earth Science Missions

	NASA Missions & Collaborators	Other Affiliated Missions
Present number	23	3
Present sun-synch	11	3
Present X-Band	6	3
Present Data rates	40-150 Mb/s	105 Mb/s
Future number	12	1
Future sun-synch	8	1
Future X-band	5-7	?
Future Data rates	30-300+ Mb/s	?

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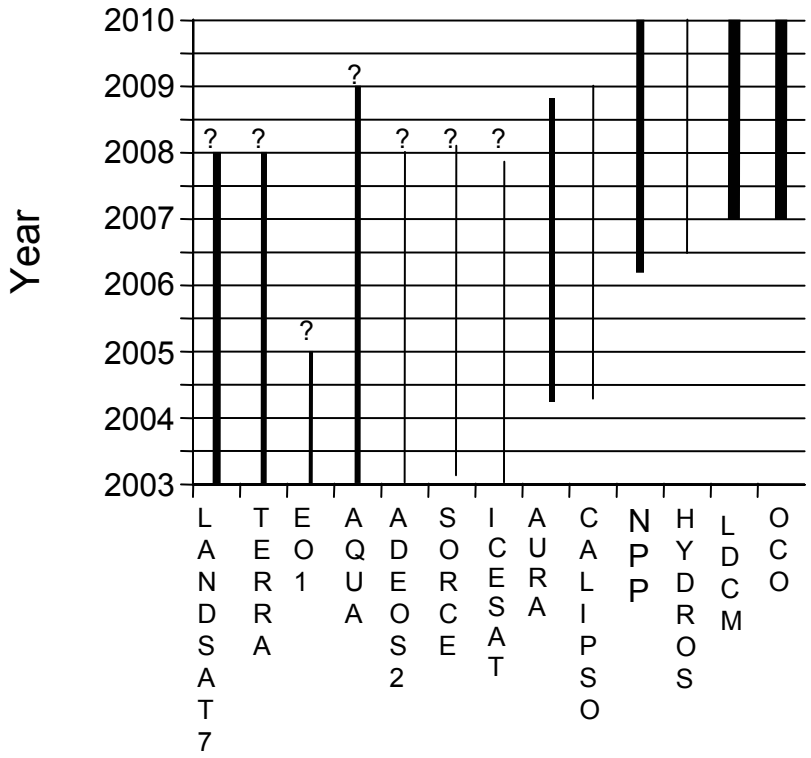

Science Satellites Using X-Band

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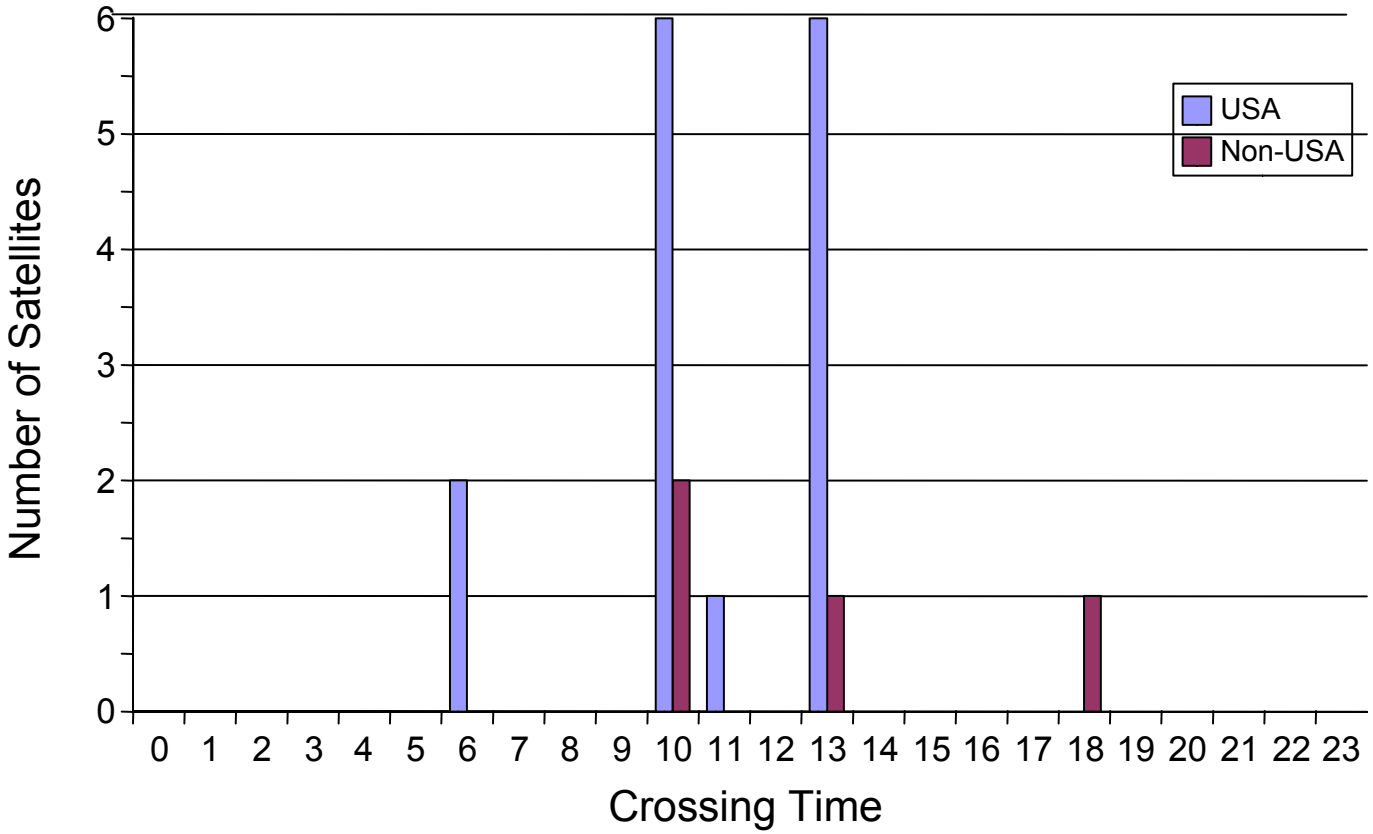

Present and Future Sun-Synchronous Science Satellites

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A few spacecraft use X-band to directly broadcast real time data (10-20 Mb/s) to any ground station in line-of-sight:

TERRA' (MODIS data only, almost all the time)
(except when it may interfere with the Deep Space Network)

AQUA* (all science data)
(except when downlinking recorded data)

NPP* (all science data)
(Should shift to 7750-7850 MHz MetSat band)

NPOESS' (all science data)
(Should shift to 7750-7850 MHz MetSat band)

The direct broadcast system and users will be described in a later paper.

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SUMMARY:

- Sun-synchronous satellites use X-band heavily, and they tend to cluster around preferred equatorial crossing times.
- Primary usage is to downlink stored science data (very high bandwidth, >100 Mb/s and getting higher). Usage is expected to increase, with each user needing most or all of the available bandwidth.
- The direct broadcast of real time data (10-20 Mb/s) is expected to taper off and relocate to a lower band.

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Backup NASA Material

NASA Earth Science Missions

Mission	Launch	Altitude	Incl.	Crossing	Rept	X-Band	Comment
	mm/dd/yy	km	deg.	LT-SunSy	days	Mb/s	
ERBS	10/05/84	585	57				Earth Radiation Budget Satellite
UARS	09/15/91	585	57				Upper Atmosphere Research Satellite
TOPEX/Poseidon	08/10/92	1336	66				Oceanography mission, preceeded JASON-1
TOMS-EP	07/02/96	740	98.4	11:10A		none?	Total Ozone Measurement
TRMM	11/27/97	402	35				Tropical Rainfall Measuring Mission
LANDSAT-7	04/15/99	705	98.2	10:00D	16	3x150	Multispectral imagery for Land cover/Land use
QuikSCAT	06/19/99	803	98.6	06:00A			Replaced SeaWinds instrument after ADEOS-1 failed.
TERRA	12/18/99	705	98.2	10:30D	16	150	Observes state of atmosphere, land, and oceans.
ACRIMSAT	12/20/99	716	98.13	22:44D			Measures total solar irradiance
SRTM	02/11/00	233	57				Mission competed, duration 11 days
GOES-L	05/03/00	36000	0				For NOAA
CHAMP	07/15/00	450	87				gravity, geomagnetic field, and atmospheric sounding
NOAA-L POESS	09/21/00	833	98.8	13:54A			For NOAA
EO-1	11/21/00	705	98.2	10:01D	16	105	Technology demo-advance land imager and hyperspectral
GOES-M	07/23/01	36000	0				For NOAA
SAGE-3 (Meteor)	12/10/01	1018	99.6	09:25A		none?	Russian vehicle, Russian downlinks
GRACE	03/17/02	300-500	89				Gravity Recovery and Climate Experiment
AQUA	05/04/02	705	98.2	13:30A	16	150	…precise atmosphere and oceans measurements
NOAA-M POES	07/24/02	833	98.8	10:00D			For NOAA
JASON-1	12/07/02	1336	66		10		Oceanography mission
Seawinds(ADEOS-2)	12/14/02	803	98.6	10:03D	4	60	Instrument on MIDORI-2 (ADEOS-2) Japanese Spacecraft
ICESat	01/12/03	600	94		183	40	Ice, Clouds, and Land Elevation Satellite
SORCE	01/25/03	600	40				Solar irradiance and spectrum measurements

NASA Earth Science Missions

Mission	Launch	Altitude	Incl.	Crossing	Rept	X-Band	Comment
	estimated	km	deg.	LT-SunSy	days	Mb/s	
AQUARIUS	2006	600	97.8	06:00?		?	Measures ocean salinity, L-band scatterometer and radiomete
AURA	winter 2004	705	98.2	13:45A	16	150	to study the chemistry and dynamics of Earth's atmosphere
CALIPSO	spring 2004	705	98.2	13:33A	16	80	key aerosol and cloud properties
CloudSAT	spring 2004	705	98.2	13:33A	16		topside cloud radar
DSCVR	spring 2020	1000000	N/A				Sun-Earth libration point observatory, formerly TRIANA
EO-3	2005	geosyn.	0				GIFTS instrument
GPM	fall 2007	400	65			TBD	Global Precipitation Mission: Improve weather forecasting
HYDROS	2006	670	97.8	600		31	Measures soil moisture, L-band radar and radiometer
LDCM	2006	705	98.2	10:00D	16	TBD	Continues supply of Landsat data via commercial vendor
NPP	winter 2006	824	98.8	10:30D		300	Joint NASA-NOAA-DoD, bridge from AQUA to NPOESS
OCO	2006	705	98.2	13:15A	16	150	Orbiting Carbon Observatory
VCL	spring 2020	400	67			?	Vegetation Canopy Lidar
Related Missions	Launch	Altitude	Incl	Crossing	Rept	X-Band	Comment
	mm/dd/yy	km	deg.	LT-SunSy	days	Mb/s	
ADEOS-2	12/14/02	803	98.6	10:03D	4	60	Japanese; Downlinks to ASF - see SeaWinds
ERS-2	04/21/95	785	98.5	10:30D	35	105	ESA; Downlinks to ASF
Parasol		705	98.2	13:40?	16	none?	French; In afternoon train
Radarsat-1	11/04/95	798	98.6	18:00A	24	105	Canadian; Downlinks to ASF
SAC-C	11/21/00	705	98.2	10:21D	16	yes	Argentinian; In morning train; Downlinks in Argentina